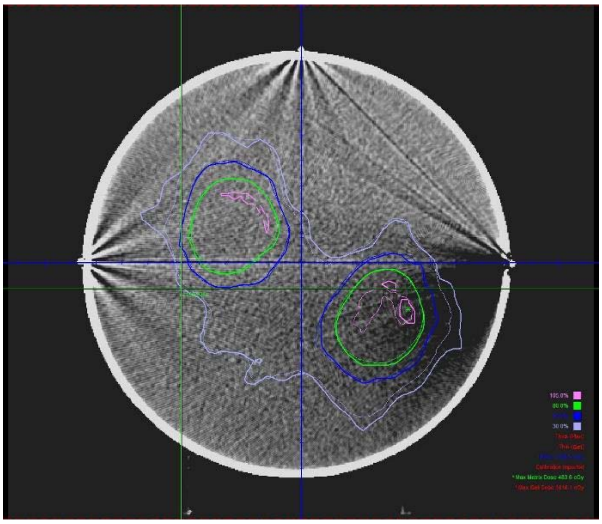

Conclusion: Polymer gel dosimetry shows promise for volumetric patient-specific QA of IMRS dose distributions. It does not present limitations when treatments involve couch rotation and gives a complete 3D assurance. However, it is labor intensive to be applicable in daily clinical practice. Nevertheless, the gel method has an important role during safe implementation of a SRS program.

PO-0821

A comparison between different patient QA devices for IMRT treatments on VERO system

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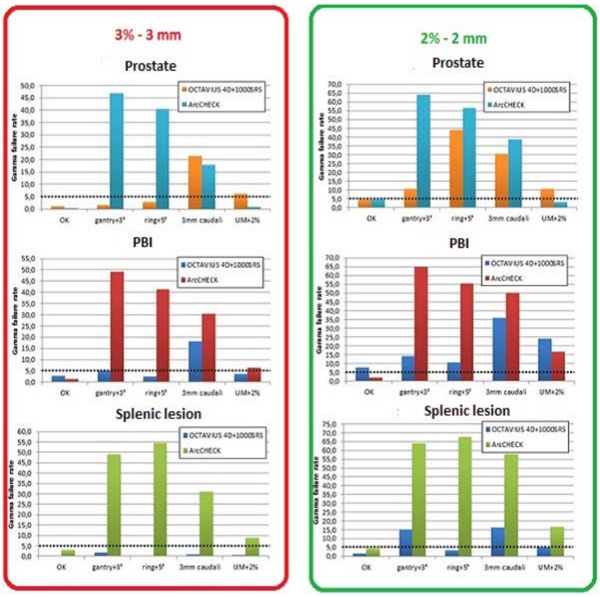
Purpose or Objective: The purpose of this study was to compare the ability of OCTAVIUS® 4D phantom with 1000 SRS array (PTW) and ArcCHECK® system (SunNuclear) in detecting geometric and dosimetric errors intentionally introduced into the IMRT step-and-shoot treatments delivered with VERO® system (Mitsubishi Heavy Industries and BrainLAB). Moreover, the impact of these errors on the DVH of PTVs and OARs was investigated.

Material and Methods: The treatment plans of 3 clinical cases were considered (prostate, partial breast irradiation PBI and splenic lesion). From each of the original plans, 4 verification plans were created, containing one intentional error per plan: gantry rotation of +3°, ring rotation of +5°, 2% increased number of monitor units and isocenter translation of 3 mm (caudal direction). All the plans were calculated with iPlan 4.5.3 (BrainLAB) with a calculation grid of 2 mm on a mathematical phantom, for OCTAVIUS® 4D system, and on the CT images (plug inserted), for ArcCHECK®. The analysis was executed applying the 3D γ evaluation method (3% local dose-3mm and 2% local dose-2mm, 10% dose threshold), comparing the original calculated distributions with the measured ones (with errors) using the related software (VeriSoft® Patient Plan Verification Software for OCTAVIUS 4D®, coronal projection, and SNC Patient™ Software for ArcCHECK®). The tolerance level considered was 5% for the gamma failure rate (an error was considered detected when the gamma failure rate was higher than 5%). The impact of the errors introduced was evaluated by considering the DVH of PTVs (D98%, D2% and Dmean), rectum (D50% and D5%), ipsilateral lung (D40% and D10%) and spinal cord PRV (Dmax) respectively. The Pearson's correlation coefficient between the variation of the gamma passing rate and the variations of the DVHs points for the PTVs and the OARs considered was also calculated.

Results: The results of the 3D γ evaluation are reported in the figure, both for 3%-3 mm and 2%-2 mm criteria, for the original plans and for the modified ones. Using McNemar's test, the total detection rate detected by ArcCHECK® was higher than that of OCTAVIUS® 4D (p= 0.045), with 3%-3 mm criteria, while it was comparable with 2%-2 mm criteria (p= 0.480).



The Pearson's correlation coefficient calculated between the variation of the gamma passing rate and the variations of the constraints for the OARs considered are shown in the table.

OCTAVIUS® 4D + PTW 1000SRS

r					
	PTV			OAR	
Prostate	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**Rectum $D_{50\%}$**	**Rectum $D_{5\%}$**
3%-3 mm	**0.848**	0.236	0.408	-0.689	**-0.994**
2%-2 mm	0.587	-0.170	0.019	**-0.840**	**-0.936**
PBI	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**Lung $D_{40\%}$**	**Lung $D_{10\%}$**
3%-3 mm	**0.899**	0.543	0.294	0.226	-0.672
2%-2 mm	0.691	0.057	-0.213	-0.048	-0.472
Spleen	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**PRV D_{max}**	
3%-3 mm	-0.131	0.135	0.248	-0.624	
2%-2 mm	0.249	0.578	0.378	**-0.777**	

ArchCHECK®

r					
	PTV			OAR	
Prostate	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**Rectum $D_{50\%}$**	**Rectum $D_{5\%}$**
3%-3 mm	0.059	0.651	0.609	**0.900**	0.502
2%-2 mm	0.283	**0.779**	**0.773**	**0.806**	0.294
PBI	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**Lung $D_{40\%}$**	**Lung $D_{10\%}$**
3%-3 mm	0.092	**0.813**	**0.949**	0.628	-0.332
2%-2 mm	0.238	**0.892**	**0.987**	0.649	-0.427
Spleen	**$D_{98\%}$**	**$D_{2\%}$**	**D_{mean}**	**PRV D_{max}**	
3%-3 mm	0.576	0.414	**0.874**	0.519	
2%-2 mm	**0.767**	0.687	**0.983**	0.323	

Conclusion: The results showed a different sensitivity to errors for the two systems, in particular in the case of ring and gantry rotations. This variation can be related to the different dose reconstruction methods applied: ArcCHECK® uses both the entry and exit dose, while OCTAVIUS® system the planar dose measured by the inserted detector and the PDD of the beam. Furthermore, no significant correlation was found between the results of the 3D γ analysis and the DVHs variations due to the intentional errors, as shown in literature.

PO-0822

Tumor margin estimation by multiple Bragg peak detection in carbon ion therapy

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Purpose or Objective: Carbon ion therapy is very sensitive to tissue density variations along the beam path. Within the lung region, due to the high-density difference between tumor and lung tissue, these variations are further emphasized, leading to miss the tumor or high-dose deposition in critical structures. Hence, it is crucial to have correct knowledge of tumor margin. If one shoots these structures with a carbon beam with energy high enough to cross the patient and detects their residual range using a range detector, multiple peaks will be present in the acquired signal. This is caused by the fact that carbons from the same beam cross different structures. The purpose of this work is to show that using information from these multiple peaks, it is possible to measure the interface position using just a few irradiation spots, thus minimizing the imaging dose.

Material and Methods: Two approaches are proposed: the single shot approach is a theoretical model, which provides a relationship between the peaks intensity and distance from the interface; such approach only requires one shot around the interface to predict its position. The second approach (inflection point) entails irradiating the interface at two different positions and through an exponential fit compute the exact interface location. Both methods are validated using Monte-Carlo simulations with different interface configurations. A Carbon Digitally Reconstructed Radiography (CDDR) method is implemented in order to assess both methods in two lung tumor cases. Positional shifts to a water density tumor are implemented and the accuracy of the proposed methods is tested.

Results: Results show that both approaches exhibit an error <1mm in determining where the interface is positioned with respect to the beam. The inflection point method showed to be the most reliable, since it allows the determination of the interface when more than two peaks are detected using prior-knowledge information. Both methods offer a low dose approach, which will potentially allow adjustment of the irradiation beam position when a tumor shift occurs.

Conclusion: By measuring the difference between the two generated peaks at an interface, it is possible to determine its exact position with 1mm accuracy. Currently tumor margin positioning/delimitation is being accessed using multiple angle approaches and considering breathing motion effects. Future work will consider applying the same methods to other tumor areas and structures which can be used for patient positioning.

PO-0823
Five-year results of treatment quality assurance using in vivo dosimetry in ocular proton therapy

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Purpose or Objective: An in-house in vivo dosimetry system based on the measurement of gamma-prompt radiation emission during irradiation was implemented for quality assurance of ocular proton therapy treatments at the Centre Antoine Lacassagne (CAL) in 2011. Based on the last five years results we report the performance and limitations of the system.

Material and Methods: Gamma-prompt radiation is emitted during proton therapy irradiation by collision of protons with beam modifiers all along the optical bench. A correlation was established at CAL between gamma-prompt radiation and the accessories conforming the clinical SOBP (range shifter and modulating wheel), by measuring, for a large set of treatment sessions, the charge cumulated (Q) at a large volume ionization chamber located inside the treatment room at 3 m from the optical bench. A power function was used to fit the dose rate D/MU and Q/D data points, where D is the dose delivered to the patient. The function was introduced to an in-house Visual Basic code to automatically retrieve the differences (d) between calculated and expected D/MU. A tolerance of 5% was established, out-of-tolerance cases requiring systematic SOBP accessories checking. Out-of-tolerance rate was calculated from more than 4000 treatment sessions performed from May 2011 to September 2015. Out-of-tolerance causes were analysed by assessing uncertainties on the ionization chamber measurement acquisition (repeatability test performed in reference treatment conditions (10 s irradiation, 13 Gy and 1.37 cGy/UM)), correlations of d with D, D/MU and Q and the impact of the customized patient accessories located just before the eye (collimators, filters and compensators).

Results: The relative differences were normally distributed and centered on 0.004% with a σ of 3%. 12% of cases were out-of-tolerance, only 2% being larger than 7%. Out-of-tolerance cases were never related to an error on SOBP accessories. More than 60% cases with differences larger than 7% were related to low dose treatments (<7 Gy). Relative differences were not correlated to the use of filters or to the collimator area. Treatments performed with compensator yielded higher differences (doses are below 7 Gy for these treatments). The uncertainty on Q acquisition was estimated to 0.8%. Cumulating Q beyond the treatment time (40 s) increased the relative difference by 2%.

Conclusion: The system is independent of the customized patient accessories located right before the eye. The precision is consistent with in-vivo dosimetry systems and yields results within or very near tolerance limits for most standard treatments performed at CAL (13 Gy). Out-of-tolerance cases could be minimized by limiting the ionization chamber measurement acquisition time. The method perfectly fulfills the goal of SOBP accessories verification, and could be further improved by reviewing the default for low dose treatments.

PO-0824
Treatment couch modeling in Elekta Monaco treatment planning system

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Purpose or Objective: This study describes the modeling of the treatment couch in Elekta Monaco treatment planning system (v. 3.30.01), and the measurements made to validate it for attenuated and skin dose calculation, and 6MV energy beams.

Material and Methods: The iBEAM evo carbon fiber couch has a sandwich design. It consists of a narrow outer layer of electron density ρE=1.7gr/cm3 and a foam core of lower density ρE=0.3gr/cm3.
First modeling was composed of a single contour. CT images were acquired and the couch contoured in each slice. The dimensions were according to vendor specification. The best agreement between experimental and computed dose attenuation was using an effective density of ρE=0.13gr/cm3.However, the comparison failed at the edges of the couch. Therefore, a second contour has been added with the thick of the edges and the density of carbon fiber ρE=1.7gr/cm3. That way, calculations vary slightly with grid size and don't depend on the order of ROIs.
A cylindrical phantom with an ionization chamber CC13 placed in the central insert was used to measure the attenuated dose. The phantom was centered laterally on the couch and the chamber position coincides with linac isocenter. Dose measurements were performed for an open 10x10 field at multiple gantry angles, Mθ, 100 Monitor Units